PEST MANAGEMENT IN FLORIDA'S COMMERCIAL FOREST NURSERIES

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ABSTRACT

Known losses to disease in Florida's commercial forest nurseries exceeded 8.2 million seedlings in 1979, representing a monetary loss of more than $120,000 based solely on seedling production costs. Important diseases are identified and discussed, and losses are reviewed in the context of overall disease impact on the State's forest nursery and regeneration efforts. The subject of "atypical" or non-pathogen-related "disease" is alluded to, and strategies for disease control are discussed.

INTRODUCTION

Florida's commercial forest nurseries produced nearly 140 million seedlings (Pinus and Eucalyptus spp.) in 1979 (Table 1). Substantial numbers of these seedlings were lost in the nursery to a variety of forest pests (insects and diseases) which continue to plague nursery managers. Although some seedlings were damaged or killed by insects, the majority of losses were directly attributable to disease. An awareness of nursery disease problems, their modus operandi, and appropriate control measures is essential for effective pest management and the production of quality, disease-free stock.

Table 1. Production of commercially important forest tree seedlings in Florida's forest nurseries in 1979.[a,b]

NURSERY	PINES			
	Slash	Loblolly	Sand	Longleaf
Munson (DOF)	12.50	3.00	1.00	0.50
Chiefland (DOF)	17.00	8.00	2.00	1.00
St. Regis	21.00	16.00	2.50	0.04
St. Joe	9.40	3.80	2.10	0.00
Buckeye	15.78	0.40	2.93	0.00
Gilman	7.25	0.64	0.16	0.06
CCA	4.50	4.50	0.00	0.30
Forest & Lakes	1.14	0.00	0.24	0.00
TOTAL	88.57	36.34	10.93	1.90

	EUCALYPTUS		
	grandis	tereticornis	viminalis
Herren (DOF)	1.230	0.011	0.007

[a] Approximate millions of seedlings.

[b] Figures supplied by respective nurserymen

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The purposes of this paper are fourfold, namely:

1) to identify and discuss current and/or (as the case may be) serious disease problems which are extant in Florida's commercial forest nurseries, some of which are relatively "new" and perhaps unfamiliar to the reader;

2) to summarize and discuss the impact of these diseases on the state's seedling production, with particular reference to the 1979 crop year;

3) to briefly allude to some potential "post outplant" consequences of "nursery" diseases; and

4) to highlight strategies being employed or considered to minimize disease losses and maximize seedling quality and subsequent field performance.

IMPORTANT DISEASES IN FLORIDA'S FOREST TREE NURSERIES

Charcoal root rot, caused by the fungus Macrophomina phaseolina (Tassi) Goid. (= Sclerotium bataticola Taub.) has, in recent years, been one of the most serious diseases affecting pine seedlings in Florida's bare root nurseries. In 1976, losses to this disease reached approximately $148,000, in one nursery, as nearly 16.5 million diseased seedlings were quarantined due to extensive infection.

Charcoal root rot is often subtle and warrants the attention of foresters and nurserymen for a number of reasons. Above ground symptom expression may include nothing more than slight stunting and yellowing of affected seedlings. Indeed, even these symptoms may be masked as a result of the optimal growing conditions (fertility, irrigation, etc.) provided by the nursery environment. Consequently, the disease may be present and yet go unheeded as a problem of any significance. In addition, M. phaseolina increases in activity in late summer when soil temperatures are at their peak, often becoming problematic when remedial action may be too late to save the affected crop. Further, M. phaseolina forms persistent survival structures (sclerotia) in the soil which are resistant to many standard fungicides and soil fumigants, and which may remain viable in the soil for years. Finally, the pathogen not only attacks pines, it also attacks a variety of other plant species including cover crops such as corn and soybeans. As a result, this fungus can easily develop into economically disastrous populations if susceptible host crops are routinely grown in rotation in nursery soils.

While losses resulting from charcoal root rot may be incurred at the nursery in the forms of seedling mortality and/or increased numbers of cull seedlings, perhaps the most serious damages are sustained in terms of lost growth and replant costs resulting from plantation failures. Loss of and/or damage to seedling roots due to infection by M. phaseolina often results in seedlings which are unable to survive stresses (drought, etc.) in the field following outplanting. In Florida, outplant performance of diseased seedlings as well as the fate of M. phaseolina transported to the field on infected stock continue to be areas of concern and investigation.

Root systems of pine seedlings infected with M. phaseolina display a variety of symptoms varying with locus of infection, environmental influences,

stage of disease development, etc. Often, diseased seedlings show a pronounced lack of feeder roots, and cortical tissues of larger roots (especially tap roots near the soil line) are characteristically swollen and exhibit a black, roughened and/or cracked appearance. Beneath these symptomatic cortex tissues, the pathogen often produces numerous, small, shiny black microsclerotia. These structures can be seen quite easily with a hand lens and are useful aids to diagnosis. However, laboratory confirmation is recommended for positive identification.

Phytophthora root rot of sand pine (Pinus clausa (Chapm.) Vasey), caused by the fungus Phytophthora cinnamomi Rands, is a problem of growing concern to forest pathologists and one which merits the concern of nurserymen and regeneration foresters as well. Both the Choctawhatchee (P. clausa var. immuginata Ward) and Ocala (P. clausa var. clausa Ward) races of sand pine are susceptible to P. cinnamomi, but damage caused by this pathogen is generally greater on sites with soils conducive to its activity; e.g., relatively heavy, poorly drained soils, or soils with a shallow impervious layer.

In nursery seedbeds, severely infected seedlings exhibit discolored foliage ranging from a slight chlorosis to bright orange-red or brown with the onset of mortality. Seedlings which are only lightly infected often fail to exhibit noticeable above-ground symptoms or simply remain stunted. Infected roots are typically darkened and the necrotic cortical tissues of infected feeder roots are characteristically prone to sloughing, exposing the woody tissues of the stele. Adventitious root development, at points behind the advancing necrosis, is not uncommon. Occasionally tap roots and/or root collars are partially or fully impregnated with resin. This symptom may or may not be accompanied by external resinosis. All of these symptoms are useful aids for diagnosing Phytophthora root rot. However, since symptoms are not always pathogen-specific, laboratory confirmation is recommended.

P. cinnamomi, like other soil-borne fungi, is spread by movement of infected nursery stock, movement of infested soils on equipment, etc., surface movement of irrigation or rainwater and/or mycelial growth through contiguous root systems of suitable host plants. The pathogen is also capable of surviving for years in infested soils in the absence of suitable host species. Understanding these aspects of the pathogen's biology is a prerequisite for effective control.

There are strong indications, both in the literature and in the results of current investigations, that a major portion of the root disease complex afflicting sand pine in the field could be a result of P. cinnamomi infection originating in the nursery. The ramifications of this very real possibility are many and serious. The critical need to control this disease problem at the nursery level cannot be overemphasized.

Fusiform rust, caused by the fungus Cronartium quercuum (Berk.) Miyabe ex Shirai f.sp. fusiforme (= Cronartium fusiforme Hedgc. & Hunt ex Cumm.) continues to be a primary concern of Florida's forest nurserymen. In recent years, nursery losses to this disease have been, for the most part, well within acceptable limits (i.e., 1-2% or less). However, the potential destructiveness of fusiform rust was dramatically emphasized in 1979 when losses in one nursery alone reached an estimated 7 million seedlings (Table 2).

Fusiform rust affects predominantly slash (Pinus elliottii Engelm.) and loblolly (P. taeda L.) pines. Symptoms on infected nursery seedlings may include some type of foliage discoloration. However, foliage symptoms are highly variable, subject to local environmental conditions, and generally not definitive indicators of rust infections. The most reliable symptom of infection is the characteristic fusiform or spindle shaped gall which develops on the stem of diseased seedlings.

Fusiform rust, like most other "nursery" diseases, can and often does have post outplant effects. Infections initiated in nursery seedbeds are often not visible (i.e., latent gall development) or are otherwise overlooked (e.g., seedlings not graded and/or culled) at lifting time. Consequently, these infections may be one component of "post outplant mortality" and/or plantation establishment failures. A realization of the source of such infections can be important to the synthesis of sound management decisions.

Rhizoctonia blight of longleaf pine (P. palustris Mill.) is a problem which, over the past few years, has caused considerable damage to seedlings in at least four commercial forest nurseries in Florida. In 1979, approximately 120,000 seedlings succumbed to this little known disease in one nursery alone (Table 2).

The pathogen, Rhizoctonia solani Kuhn, is perhaps best known by foresters and nurserymen as a primary cause of seed (pre-emergence) and seedling (post emergence) damping-off. However, longleaf pine seedlings by virtue of their "grass stage" development and the characteristic soil-line habit of the fungus, are uniquely prone to infections, long after they would normally be vulnerable to "damping-off". As infection proceeds, the bases of affected needles become chlorotic, discolored, and/or water-soaked and eventually rot. Rot is also common on stem and bud tissues at or near the soil surface as well as on roots in the upper layers of soil. Infection also occurs on distal needle parts as a result of needles touching the soil surface. Diseased seedlings usually become completely discolored and die, and affected seedbeds are characterized by circular to irregular patches of dead and dying seedlings. The effect(s) of nursery initiated R. solani infections on subsequent field performance is unknown.

Presumably, nursery seedbeds are initially colonized by 1) residual populations of R. solani in seedbed soils either in the form of persistent sclerotia or saprophytically surviving mycelia; 2) aerially disseminated basidiospores of Thanatephorus cucumeris (Frank) Donk (the sexual stage of the pathogen); and/or 3) introduction of R. solani on unclean seed. (Non sterilized pine straw or other natural mulching materials might also provide a mode of entry for the pathogen. This possibility is being investigated.) Disease spread within seedbeds is affected by mycelial growth from seedling to seedling via direct contact or through soil and/or the physical movement of infested soil via machinery, irrigation, etc.

Pitch canker, caused by Fusarium moniliforme Sheld. var. subglutinans Wollenw. and Reink., is well known for the damage it causes to trees of intermediate and older ages in plantations and seed orchards (Ref. paper by G. M. Blakeslee, these proceedings). In August of 1979, this disease was identified for the first time as a cause of late season mortality of first-year

slash pine seedlings in commercial forest nurseries. Extensive surveys revealed this problem to be widespread in Florida, with diseased seedlings detected in each of seven nurseries examined. In general, nursery losses resulting from pitch canker infections were not considered serious (Table 2). However, loss estimates available at this time are regarded as conservative, and the contribution of nursery infections to post outplant mortality has not yet been fully evaluated.

Late season symptom expression by infected slash pine seedlings includes: 1) foliage discoloration ranging from slightly off-color to yellow-green and eventually red-brown with the onset of mortality; 2) wilting of foliage and the succulent portion of the upper stem, often accompanied by a drooping of the growing tip; and 3) occasional flattened or depressed areas on the lower stem from which resin frequently exudes resulting in the adherence of small aggregates of soil at the cankered site. In addition, small, salmon-pink sporodochia (fruiting bodies) and diffuse powdery growths of the pathogen are sometimes visible on symptomatic stems and/or root collars.

The most consistent and reliably diagnostic symptom on late season symptomatic seedlings is the presence of a pitch-soaked lesion on the lower stem. Lesions are most frequently located at or near the soil line, but are also found in the region of the cotyledonary node. In advanced stages of lesion development, resin often occludes the entire cross section of the xylem in infected stems. Lesions can be readily observed in the field by careful dissection of symptomatic stems with a sharp knife, etc.

Generally, diseased seedlings occur as scattered individuals throughout nursery seedbeds. However, small clusters of infected seedlings exhibiting one or more stages of symptom development are not uncommon. These clusters are suggestive of localized (secondary) spread of the pathogen within infested seedbeds. It is possible that conidia (asexual spores) produced on infected seedlings are playing significant roles in this pattern of disease development.

Researchers at the University of Florida and the U. S. Forest Service are currently investigating several aspects of this "new" pitch canker problem. Research is aimed at: 1) identifying the source(s) of primary inoculum (i.e., how the pathogen gets into nursery seedbeds); 2) understanding the epidemiology of the disease (i.e., how the disease develops and spreads); 3) determining the actual and potential impacts of the disease; and 4) developing appropriate control measures (ref. papers by G. M. Blakeslee and T. Miller, these proceedings).

"Tip blight" of Pinus spp. caused some concern among Florida's forest nurserymen in 1979. This disease, of as yet uncertain etiology (i.e., cause is unsubtantiated) apparently appeared simultaneously in forest nurseries across the South in late summer (C. E. Cordell and C. E. Affeltranger, personal communication). In Florida, "tip blight" is known to have occurred in at least three commercial forest nurseries; disease incidence varying among nurseries. Loblolly, slash, and sand pines were affected in Florida, but the relative incidence of disease was appreciably higher in loblolly seedbeds. A limited survey of one nursery in north Florida revealed a 4.8, 1.0, and 0.24% incidence for the three species, respectively (D. Miller and R. Brooks, personal communication).

Seedlings suffering from "tip blight" are recognizable by a distinct discoloration (usually orange-red) of the foliage on the upper 1-2 inches of the growing tip. In the early stages of disease development, purple colored lesions are commonly visible on upper stems, frequently at the base of dead and/or dying needles. Multiple lesions are sometimes present on one seedling, and in time, all tissues near and above these lesions, including the terminal bud, die. In many cases, diseased growing tips lean or tilt to one side, or even become detached and fall off as a result of stem constrictions and structural weakening at the point of lesion development.

To date, several fungi have been found in association with this disease. Among these, a Phomopsis sp. has been the most consistently recovered organism. Other associated fungi include a Sphaeropsis sp. (and/or a Diplodia sp.) and miscellaneous Fusarium spp. In the absence of definitive pathogenicity studies these fungi, as well as other possible causes, can only be regarded as possible or probable causes.

Fortunately, by lifting time diseased seedlings show practically no trace of symptoms, with the possible exception of small scars from previous infections. This disease is apparently not progressive or lethal and is not considered at this time to be cause for concern. This does not mean, however, that nurserymen should disregard this problem altogether. A watchful eye and some good field notes are encouraged.

Cylindrocladium scoparium Morgan, a widespread fungal pathogen on a variety of plant species including forest trees, has caused severe damage to container-grown eucalyptus crops in south Florida over the past two years. Losses in one nursery alone have reached nearly 220,000 seedlings, including 1/2 of one 1979 Eucalyptus grandis W. Hill ex Maiden crop (Table 2). C. scoparium is endemic to Florida and is commonly recovered from leaf spots on Eucalyptus spp. in the field. Under nursery conditions including close spacing of seedlings, overhead irrigation, high relative humidity, and comparatively high temperatures, the fungus becomes a highly virulent and destructive pathogen on seedling eucalyptus.

Infections begin primarily as leaf spots, although stem lesions indicative of direct stem infections are sometimes present. With time, infections progress to a blighting of the lower foliage, accompanied by severe lesions or cankers on the lower stem. These stem lesions develop from a rather superficial browning of the outer cortical layers to a black and/or "constricted" canker, completely encircling the infected stem. Lesions are frequently centered at points of leaf petiole attachment, suggesting a progress of infection from leaves to stems through the petioles. Heavily infected seedlings often die in the nursery, but more frequently, severely damaged seedlings simply break off at the point of stem lesion development and are rendered unsuitable for outplanting.

Limited outplant trials have shown that seedlings with slight to moderate infections present no serious problem in terms of outplant performance. Survival and growth of such seedlings following outplanting does not differ appreciably from that of disease-free seedlings. Apparently, disease development is largely arrested once seedlings are removed from the nursery environment. Heavily infected seedlings, on the other hand, represent a very poor risk in terms of outplant success. Although a few of these seedlings will "come back"

by means of root sprouts, etc., most fail altogether. Evidence suggests that root infections by C. scoparium are involved in these situations.

Results of a fungicide screening trial, conducted in south Florida in 1979, indicate that adequate control of this disease problem may be achieved in the nursery with applications of chlorothalonil and/or benomyl.

IMPACT INTERPRETATIONS

Table 2 summarizes the known losses to disease in Florida's commercial forest nurseries during the 1979 crop year. While the figures therein are accurate for "known losses in 1979", some interpretational comments are in order. For example, losses in Florida's nurseries to fusiform rust during 1979 were exceptionally high, due primarily to disastrously high levels of infection in only one nursery (see text, above). In "normal" years, losses to this disease would perhaps be more in the range of 0.5 - 1.0 million seedlings.

Table 2. Estimated losses to known disease in Florida's commercial forest tree nurseries - 1979.

Disease	Host	Loss[a]	Value @ Cost[b]	Acres Not Planted[c]
Fusiform rust	Slash pine	7,500,000	$97,000	10,000
Cylindrocladium	Eucalyptus	200,000	16,000	267
Phytophthora	Sand pine	400,000	4,800	533
Rhizoctonia	Longleaf pine	120,000	1,800	160
Pitch canker[d]	Slash pine	65,000	850	87
TOTAL			$120,950	11,047

[a]Number of seedlings.

[b]Based on Division of Forestry "cost/1000" figures.

[c]Assuming 750 trees/acre.

[d]Estimate based on only 6 or 8 nurseries (Dr. G. M. Blakeslee, personal communication).

Losses ascribed to pitch canker in Table 2 must be regarded as conservative. Not only is the 65,000 seedling loss figure based on evaluations of only six of eight commercial forest nurseries in the State, but it is an estimate of seedlings exhibiting symptoms at only one period in the production of the nursery crop (i.e., late in the growing season, prior to lifting). Current research efforts are identifying substantial additional losses due to infections which cause seedling mortality throughout the nursery growing

season and in the field subsequent to outplanting as a result of pathogen carry-over (G. M. Blakeslee and T. Miller, personal communication).

The figures in Table 2 reflect only the loss of seedlings which never made it to the field. This is only one aspect of the impact of forest nursery diseases. Perhaps equally significant as components of the overall impact of "nursery" diseases are the carry over effects which are never realized until the seedlings are outplanted in the field. (Such effects have been alluded to previously in this paper.) Carry-over effects are known for certain diseases (e.g., latent gall development in the case of fusiform rust) and are currently being evaluated for others (e.g., pitch canker, charcoal root rot). A full realization of the impact of "nursery" diseases awaits the detailed evaluation of the effects of individual diseases on the subsequent field performance (i.e., survival and growth) of nursery seedling crops. Indeed, if particular disease causing agents are introduced into planting areas on infected nursery stock, what are the ramifications for future rotations of forest tree crops? The carry-over effects of many of Florida's important forest nursery diseases (e.g., Rhizoctonia blight of longleaf pine, Phytophthora root rot of sand pine) are in critical need of evaluation. Until such effects are adequately understood and quantified we must regard the bottom line of Table 2 as a conservative estimate of impact.

Finally, in its fullest sense, disease impact must also consider the overall costs of forest (nursery) management which are directly or indirectly attributable to diseases and/or their causal agents (pathogens). Table 2 summarizes monetary losses only as a function of the value of seedlings lost in the nursery. No attempt has been made to include the costs of such practices as soil fumigation and routine fungicide applications aimed at preventing or minimizing disease infections. As a measure of the impact of disease on Florida's forest nursery crops Table 2 might, in many senses, be considered the "tip of the iceberg".

"UNEXPLAINED" OUTPLANT MORTALITY AND STAGNATION SYNDROME

Not all maladies affecting the quality and performance of seedlings in forest tree nurseries are "typical" disease problems. In recent years, there has been substantial concern on the part of forest managers and regeneration specialists over a generally poor field performance record for seedlings produced in many of Florida's commercial forest nurseries. During the past two years, considerable effort has been expended by scientists at the Florida Department of Agriculture and Consumer Services and the University of Florida to identify the causes(s) of this "unexplained" mortality and seedling "stagnation" (failure to grow) syndrome. Several problems, some of which are not necessarily startling discoveries, have been identified as probable contributors to the generally unacceptable field performance. Among these are: 1) the loss of fine roots as a function of machine lifting seedlings; 2) sub-optimal seedbed physical and chemical properties, apparently resulting in physiologically deficient seedlings; and 3) microbiological contamination of seedling packing materials having adverse effects on seedling roots. These and other aspects of seedling quality are continuing to receive the attention of foresters and researchers alike. A preliminary report of this work is to be presented at the Southeastern Area Nurserymen's Conference, to be held at Lake Barkley in Kentucky during September of this year.

STRATEGIES FOR NURSERY DISEASE MANAGEMENT

Effective management of forest tree nurseries so as to minimize losses to disease must be an integrated process. The prudent nursery manager employs a host of strategies including: 1) good soil management (effective use of fertilizers, organic amendments, cultivation, etc.); 2) adequate, but not excessive irrigation; 3) selection of clean, quality seed; and 4) sound seedbed preparation and sowing practices to insure a crop of vigorous, quality seedlings. Though perhaps unrealized, all of these practices can and often do play direct roles in the development of disease. Disease is a function of pathogen, host, and environment; any management practice affecting one of these components will invariably affect the other two, either directly or indirectly. An understanding of how specific management practices may or may not affect disease organisms and processes is a fundamental part of "integrated pest management" in forest tree nurseries.

In many cases, direct control of specific disease problems is expedient and/or necessary. The use of direct control measures where they are safe, effective, required, and registered as necessary is just as much a part of an "integrated pest management" program as is any other strategy or approach. In Florida, as in other parts of the country, the adoption and implementation of judicious soil fumigation programs (employing various formulations of methyl bromide and chloropicrin) has done much to minimize losses to root diseases such as Phytophthora root rot and charcoal root rot. Also, the use of aerial spray programs for certain types of diseases continues to be an invaluable weapon in the management of forest nursery diseases. Perhaps the most familiar of these is the use of ferbam to control fusiform rust.

Cover crop selection can play important roles in the overall management of nursery diseases. Populations of certain soil-borne pathogens can build up to dangerous levels on cover crops which are suitable hosts and provide an adequate food base for the pathogens. In Florida, cover crops of pearl millet and rye grass have been favored over corn and soybeans in recent years in order to minimize development of M. phaseolina, the charcoal root rot pathogen.

Another measure being explored as an integral part of nursery disease management or control is discriminate seedbed site selection (i.e., growing seedlings of certain species in nurseries or locations within specific nurseries where soils, etc. are best suited to the species being grown and/or least suited to the development of potentially dangerous pathogens). For example, Rhizoctonia blight of longleaf pine is, on the basis of observations to date, considerably more damaging in sandy soils as opposed to heavier, less sandy soils. On the other hand, Phytophthora root rot is more damaging to sand pine in heavier, less well drained soils than in sandier soils. Favoring the production of sand pine seedling crops on more sandy, well drained nursery sites and longleaf pine on heavier soils may, in and of itself, provide significant control of these two serious disease problems.

Finally, new strategies and/or products are constantly being developed and tested for control of disease in forest tree nurseries. A recently developed fungicidal spray program is having dramatic effects on the development of C. scoparium in container eucalyptus nurseries in south Florida.

Trials are currently under way evaluating the efficacy of several fungicide materials for the control of Rhizoctonia blight of longleaf pine and pitch canker of slash pine in nursery seedbeds. Bayleton®, a promising systemic fungicide, has demonstrated great potential for fusiform rust control and is being semi-operationally evaluated in three Florida nurseries this year. This material, in all probability, will be available for use in Florida on a 24-C label in the 1981 crop year. Alternatives to expensive soil fumigation for soil-borne pathogen control are also being considered. A technique known as "solar pasteurization of soils" will hopefully be tested in Florida's commercial forest nurseries in the near future. Disease control in forest tree nurseries is a dynamic process. The nursery manager must develop his control program so as to capitalize on all known aspects of seedling and pathogen biology, and at the same time be ready to adjust to changes in host or pathogen behavior, as well as the development of new information and/or control strategies.

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